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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:
Charles J. Moses, et al.

Serial No.: 10/767,587 Confirm 6194

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For: High Temperature Flexible Pipe Joint

Group Art Unit: 3679

Examiner:

Atty. Dkt. No.: 11666.0138.NPUS00

INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

Sir:

Pursuant to the duty of disclosure under 37 C.F.R. § 1.56, it is respectfully requested that the following information be considered by the Examiner and made of record.

This patent application is assigned to Oil States Industries, Inc. (hereinafter "Oil States"). Early development with respect to the invention included a proposal initiated by Oil States in 1996 for a joint industry program (JIP) to accomplish the following:

(1) identify test parameters for a flexible pipe joint;

(2) test elastomeric compounds and adhesive bond systems;

(3) investigate an initial design for temperature resistance;

(4) conduct a heat transfer finite element analysis study of the flexible pipe joint design;

(5) fabricate, instrument, test and analyze a flexible pipe joint to determine its heat transmission properties. (See Exhibit A, Joint Industry Program for High Temperature FlexJoints, Oil States Document No. SP1K-23-040, Rev. A, 15 July 96, 17 pages).

The JIP study was conducted by Oil States with the participation of Shell Offshore and Statoil A.S. During the JIP study, testing was confined to a small-scale (4") high-pressure flexible pipe joint prepared specifically for the JIP study. At the completion of the JIP study, a report was issued that summarized the results as follows:

(1) the thermal conductivity, specific heat, and diffusivity of three Oil States elastomeric compounds were established for future use;

(2) an elastomer to metal bonding system was selected for use at temperatures up to 130 °C (266 F);

(3) an Oil States elastomeric compound did not degrade at a temperature of 82 °C (180 °F); and

(4) Oil States can manufacture a flex element according to engineering drawing specifications;

(5) Teflon provided the greatest temperature reduction at the elastomer for a 130 °C (266 F) condition;

(6) a flexible pipe joint could function at 130 °C (266 °F) if a thermal barrier could be designed that would be suitable for flowline service conditions.

In short, the JIP study suggested that a flexible pipe joint designed to operate at 130 °C (266 °F) might be feasible. (See Exhibit B, Joint Industry Program High Temperature FlexJoint Final Report, Oil States Document No. SP1E-23-090, 8 pages.)

After the JIP study, further development began in early 2001 with two project-oriented studies for an ExonMobil Erha Project and a BP Crazy Horse Project (later named Thunder Horse Project). In each case, a confidentiality agreement was initiated at the onset of discussions about a high temperature flexible pipe joint. Due to BP's financial investment in the development, a representative of BP has been onsite at Oil States to monitor the quality of the process and witness the testing procedures. Oil States was also obligated to prepare periodic progress presentations to BP.

The ExxonMobil Erha project took place between March 2001 and March 2002. This project included evaluation of selected elastomers for use in a high-temperature flexible pipe joint. (See Exhibit C, Exxon-Erha FlexJoint Prelimiary Design Summary, Oil States, 18 June 2001, pp. 1-22.) An objective of this project was to produce four 12" production riser SCR flexible pipe joints having a 115 °C maximum design temperature, and preliminary prices were quoted for these four flexible pipe joints. (See Exhibit D, Proposal for the Provision of FlexJoints for the Esso Exploration and Production Nigeria Ltd Erha Project EPC2, Oil States Document SP1K-23-113, Rev 0, June 28, 2001, page 2-1 and page 3-9.) The first phase of this study was to evaluate existing elastomeric compounds with the intent of selecting the most successful for further evaluation. The next phase of this study was to select the most suitable elastomer from refined variations of the most successful elastomeric compound. Oil States then

began a characterization of high temperature elastomer. However, no production riser flexible pipe joints were produced during this project.

The BP Thunderhorse project began in 2001 in parallel with the Exxon Mobile Erha project. (See Exhibit E, Crazyhorse 12-In. Import FlexJoint Design, Oil States, 10 May 2001, pp. 1-28.) An objective of this project was to produce four 12" high-temperature, high-pressure (HTHP) production riser SCR flexible pipe joints, and preliminary prices and scheduling were quoted for these four flexible pipe joints. (See Exhibit F, 12" High Temperature / High Pressure (HTHP) SCR FlexJoint Design Study for the BP Crazy Horse Project, Oil States Document No. SP1E-23-163, 31 Aug. 2001, pages 65, 67, and Appendix A.)

By October 2002, an engineering design phase of a 12" HTHP flexible pipe joint had been carried out, and the design had been submitted to BP for review. This design phase included a review of all specifications and development of design methodology; a preliminary analysis of the HTHP flexible pipe joint design for conformance to envelope requirements; a review of preliminary analyses and examination of possible modifications for improvement; elastomer selection; complete structural, thermal, and fatigue analyses of the design; and review of the final design. The maximum design temperature was 235 °F. The selected elastomer was a nitrile compound with a modified cure system. The elastomer layers, steel reinforcements, and elastomer cover in the design were evaluated using finite element analyses. Compenol water-glycol solution was selected for the fluid to fill the internal cavity about the bellows. The

internal cavity was to be sealed from the production fluid by metal-to-metal seals at the top and bottom of the bellows. A 30% glass fiber filled polyetheretherketone (PEEK) thermoplastic was selected to be the thermal barrier material. An Inconel metal cover was to be welded to the extension over the PEEK material. The thermal barrier configuration selected at that time consisted of a set of five PEEK rings that mated together inside the upper section of the extension (See Exhibit G, thermal barrier configuration Figure 5-53, and Appendix A flexible joint summary drawing dated 30 October 2002.) The first four PEEK rings were to be full circumference rings with mating profiles matched-machined and bonded to the upper section of the extension. The fifth and final ring was to be divided into five individual segments that interlock as they are installed between the top face of the previously installed lower PEEK rings and an Inconel metal ring welded to the top of the extension. Two PEEK shear pins were to be inserted into pre-drilled holes in the last segment to secure it in place to the full circumference ring below it. Araldite 2014 high-temperature epoxy was selected to bond the PEEK rings in place.

To refine the details of the HTHP flexible pipe joint design, structural and thermal finite element analysis (FEA) using two-dimensional and three-dimensional models was continued until at least 31 January 2003. The thermal analysis included computational fluid dynamic analysis (CFD) using three-dimensional models of the flexible pipe joint with its high temperature hardware. The hardware configuration was approved on 10 February 2003 for fabrication of a full-scale prototype of a 12" high-temperature flexible pipe joint.

The BP Thunderhorse project included fabrication of the full-scale prototype of the 12" high-temperature flexible pipe joint. This was the first time in Oil State's development that a polymeric heat barrier, high temperature flex element configuration, and metallic bellows with barrier seal and high temperature stable, incompressible annulus fluid were brought together in a single unit to combat the thermal degradation of the molded laminated bearing in a high temperature flexible pipe joint. Final fabrication was completed about 30 April 2003, and initial testing of the full-scale prototype began on 2 May 2003. Testing was terminated due to technical problems with the elastomer composition and bonding system, but at the time testing was terminated, the temperatures at the critical areas in the flex element had stayed within the acceptable range indicating that the temperature control enhancements had functioned as designed.

Respectfully submitted,

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